Rhotic contrasts in Arabana

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ABSTRACT

Arabana has a three-way rhotic phoneme contrast: /r/ (alveolar trill) vs /ɾ/ (alveolar tap) vs /ɻ/ (retroflex continuant). The rhotic contrasts are prosodically restricted in Arabana. The triple contrast only appears following the tonic vowel, which is the first vowel. In other onset positions /ɻ/ is contrastive, but there is no /r/ vs /ɾ/ contrast. There is no contrast in coda positions. We undertook the first-ever production study of Arabana rhotics. Recorded audio materials were independently coded in PRAAT by two trained transcribers. We found the following allophony: /r/ [r, ɾ, ɹ]; /ɾ/ [ɾ, ɹ], /ɻ/ [ɻ]. The /r/ vs /ɾ/ contrast is thus negatively determined, /r/ permits [r] realizations, but /ɾ/ does not. The commonest realization of both /r/ and /ɾ/ is [ɹ]. The phoneme in neutralized coda position is /r/. The high degree of overlap in realizations between /r/ and /ɾ/ accords with reported perception difficulties.

1. INTRODUCTION

Arabana is a highly endangered language of northern South Australia. It is analysed as having a three-way phonemic distinction in rhotics between an alveolar trill /r/, an alveolar tap /ɾ/, and a retroflex continuant /ɻ/ [6] (see Table 1 for the full phonemic inventory). Three-way rhotic distinctions are rare in Australia [4], and more generally [12]. In Arabana, this three-way opposition is neutralized in various ways. The full distinction is only found in onsets immediately following the tonic vowel, which is the first vowel in a word: e.g. /ˈparu/ 'bony bream' vs /ˈpaɾu/ 'yellow ochre' vs /ˈpaɻu/ 'light'. In coda position (before a consonant), there is no distinction. In other post-tonic onset positions, not immediately following the tonic vowel, the continuant is distinguished, but there is no tap vs trill distinction. Patterns of phonetic realization in neutralized positions are not discussed in the available materials. Hercus [6] notes further that speech speed is a significant variable in contrastive positions with the trill showing lenited tap realizations at conversational speech rates. To date, there has been no quantitative research on the phonetics of rhotics in Arabana. There is no data on patterns of realization in positions of contrast, nor in positions of neutralization, nor on how realizations in positions of contrast and neutralization relate to one another. To address this lacuna, we undertook a production study of apical stops and rhotics in Arabana.

	lab	den	alv	rfx	pal	vel
stop	p	t̪	t	ʈ	c	k
nasal	m	n̪	n	ɳ	ɲ	ŋ
lateral		l̪	l	ɭ	ʎ	
(rho.) trill			r			
(rho.) tap			ɾ			
(rho.) cont				ɻ		
semi-vowel	w				j	

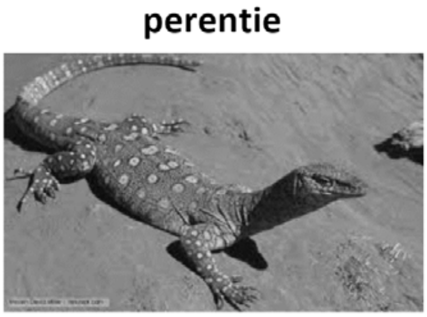
Table 1: Phonemic inventory of Arabana in IPA adapted from [4]. Rhotic segments in grey. There are four phonemic vowels: /i, u, a, aː/.

2. METHODS

2.1. Stimuli and recordings

The data derives from recordings made by author 5 of author 4, a male Arabana speaker in Alice Springs, Australia, in July 2018. Author 4 is a first language speaker of Arabana, who is literate in both Arabana and English. Author 5 initially reviewed a 120-word runsheet (extracted from [7]) with author 4. He rejected some words and provided much commentary. This resulted in a list of 25 headwords sampling apical stops and rhotic segments from two vowel environments (a_a and i_i) and three syllabic environments: (1) first post-tonic onset (Ons1), e.g. [w**iɻi**mpiri] 'wing feathers'; (2) other post-tonic onset (Ons2/3), e.g. [mank**ara**] 'young, unmarried girl'; (3) coda of tonic syllable (Coda), e.g. [ŋ**arka**] 'twilight'. Headwords were grouped according to syllable and intervocalic environment. Each headword was assigned a unique identifier and a visual stimulus in MS Powerpoint was created (see Figure 1 for an example). The headwords were randomized for five separate recording sessions made on consecutive days. A Zoom H5 Handy Recorder with an in-built microphone (sampling rate of 48 kHz and 24 bits per sample) was used to make the audio recordings. Prompted by the visual stimuli, author 4 was recorded producing between 5 and 8 (median 6) tokens of each headword on each of the 5 sessions. Headwords were produced in isolation, without a carrier phrase. Author 5 annotated the audio data in ELAN.

Figure 1: example of visual stimulus slide [10] for eliciting [pirinti] ‘perentie (goanna sp.)’.



2.2. Annotation procedure and word selection

Each headword was presented to the annotators with the segment of interest removed, e.g. [wiɻimpiri] → [wi_impi_i] (‘wing feathers’), where the underscores represent a rhotic. Each token was transcribed and manually segmented using TextGrid files generated in *Praat* 6.0.43 [2]. Two phonetically trained annotators independently transcribed each token using identical *Praat* spectrogram settings (Frequency range = 0-8 kHz; Dynamic range = 40.0 dB, window length 0.005; mean intensity (db) overlayed). Figures 2-5 show spectrograms and partial waveforms illustrating prototypical realizations of [r, ɾ, ɹ, ɻ].

Figure 2: Trill [r] in [karanda] ‘to tie up’: Two breaks in formant structure, indicating two closures, with the first break followed by burst.

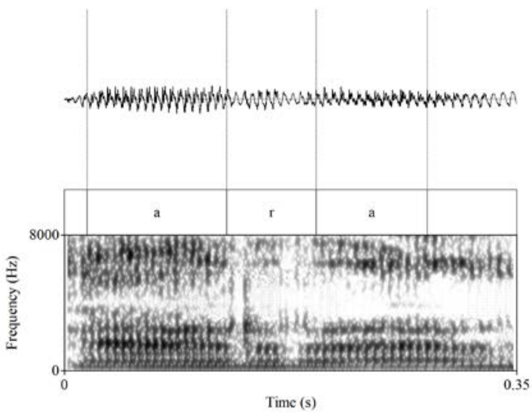


Figure 3: Tap [ɾ] in [aɾata] ‘above’: Break in formant structure, indicating closure, followed by a burst.

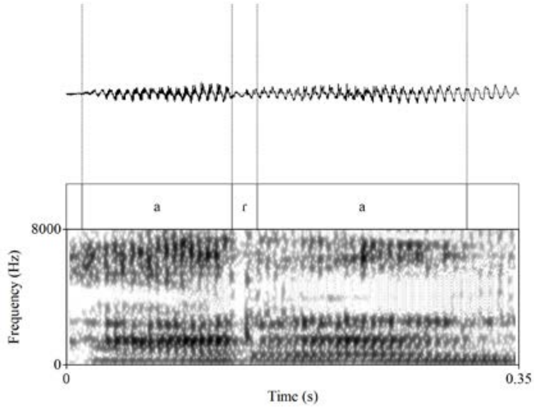


Figure 4: Continuant [ɹ] in [aɹata] ‘above’: Continuation of formant structure with attenuation of broadband energy visible in high frequency.

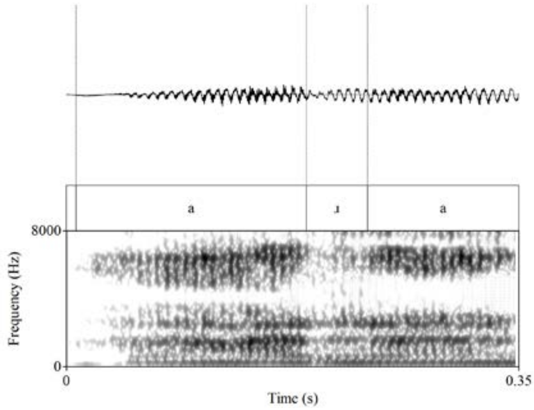
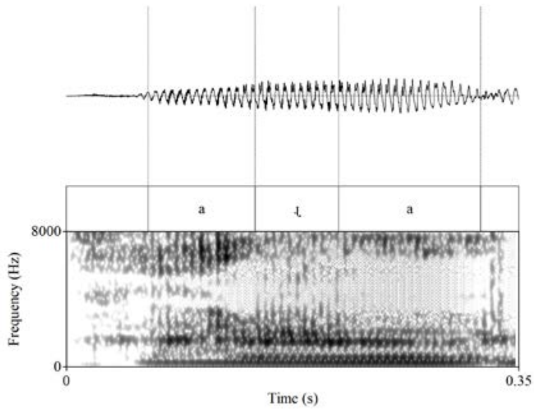


Figure 5: Continuant [ɻ] in [kaɻada] ‘north wind, hot wind, heat’: Continuation of formant structure with lowering of F3 on proceeding vowel. .



Phonetic transcription was based on a set of acoustic criteria, supported by auditory impressions. Two standard acoustic correlates of retroflex articulation were used to confirm auditory impressions of place opposition between alveolar and retroflex approximants: (1) Lowering of F3 in the transition from the proceeding vowel (e.g. [5], [9]); and (2) F3–F2 convergence (e.g. [11]).

For taps and trills, evidence of short apico-alveolar contact and oral openings (two or more for trills) were determined by a combination of the following: (1) reduction in the amplitude (dB) in the waveform relative to the spectral envelope; (2) a corresponding drop in mean spectral energy (in dB); (3) attenuation of broadband energy visible in the spectrogram between ~500 – 5000 Hz (with loss of formant structure). If the formant structure was not lost even though attenuated, then the segment was coded as a continuant (Fig. 3, 4). Trills were distinguished from taps where these criteria were met multiple times, indicating more than one cycle of closure and apico-alveolar contact. Based on these criteria, we distinguished four phonetic realizations: [r] (alveolar trill); [ɾ] (alveolar tap); [ɹ] (alveolar continuant); [ɻ] (retroflex continuant).

From a pool of 870 tokens (= 5 sessions * 29 segments * median 6 tokens), the two annotators produced 626 and 703 transcribed tokens respectively, rejecting the rest. The reasons for rejection include: (1) divergent forms with obscured elicitation environments, (2) speaker’s self-correction, or (3) background noise. A reliability test was then conducted between these two sets of tokens. Out of 649 tokens for which both annotators had a transcription, 473 tokens agreed on both place and manner of articulation (72.88%). These are the basis for the following analysis.

3. RESULTS & ANALYSIS

Table 2 shows the frequencies of the tokens of [r, ɾ, ɹ, ɻ], sorted by syllable environment (see section 2.1) and vowel environment.

		Phonetic realizations			
Syllable position	Vowel enviro -nment	alv trill [r]	alv tap [ɾ]	alv cont [ɹ]	rfx cont [ɻ]
Coda	a_Ca	**74**	25	2	0
	i_Ci	0	2	**53**	0
Ons1	a_a	8	**40**	27	34
	i_i	0	0	**51**	24
Ons2/3	a_a	30	**33**	25	6
	i_i	0	0	**35**	4

Table 2: Frequency of each annotated segment (columns) by syllable and vowel environment (n = 473). Bolded cells indicate the most frequent segment for that environment.

There are four principal observations from Table 2. First, the alveolar continuant, a realization not discussed in Hercus, is the commonest alveolar realization (n = 405): [ɹ] 193 (48%); [r] 112 (28%); [ɾ] 100 (24%). Second, vowel environment has a major effect on the distribution of alveolar realizations: (1) a_(C)a [r] 112 (42% of alveolar realizations); [ɾ] 98 (37%); [ɹ] 54 (21%) (2) i_(C)i [ɹ] 139 (99)%; [ɾ] 2, 1%; [r] 0 (0%). Third, syllabic environment affects the distribution of alveolar realizations, with coda and Ons2/3 positions showing a substantially greater number of trill realizations (n = 112) than Ons1 position: Coda, 74 (47%); Ons2/3, 30 (20%); Ons1, 8 (4%). Fourth, retroflex realizations are absent in Coda position.

The distribution of phonetic realizations does not map straightforwardly to that of proposed phonemes in the dictionary. For example, it is not the case that all [ɾ] tokens are realizations of /ɾ/. Rather, both [ɾ] and [ɹ] may be realizations of /r/ and of /ɾ/. The difference between /r/ and /ɾ/ in terms of realizations is that /r/ shows trill [r] realizations, whereas /ɾ/ does not. For example, /ka**r**anda/ ‘to tie up’ has [ka**r**anda], [ka**ɾ**anda] and [ka**ɹ**anda] as potential realizations, whereas /a**ɾ**ata/ ‘above’ has only [a**ɾ**ata] and [a**ɹ**ata] as potential realizations. This distribution of potential allophony among tokens of the same headword segment can be analysed in terms of standard lenition relations. The classic phonological analysis of variation between fortis and lenis realizations in post-vocalic environments is that the underlying phoneme is fortis, with lenis realizations being particularly favoured in intervocalic position (e.g. [3]) and at faster speech rates [1, 8]. We follow this standard analysis and propose phonemes independently of the dictionary forms. We assigned the phonemes to headwords based on the “most fortis” (leftmost on the cline) realization recorded for that headword.

		Allophonic realizations (fortis → lenis)		
Phoneme		trill	tap	cont
alv trill	/r/	[r]	[ɾ]	[ɹ]
alv tap	/ɾ/		[ɾ]	[ɹ]
rfx cont	/ɻ/			[ɻ]

Table 3: Standard lenition relations

For example, if a headword was recorded with allophones [r, ɾ, ɹ], then we assigned it /r/. If [ɹ] was the only recorded allophone (which does not exist as a phoneme per se in our analysis), we assigned it the dictionary form – this was usually the trill [r]. Table 4 summarizes how our proposed phonemes are realized as the allophones transcribed.

Our analysis shows a three-way rhotic contrast: /r/ vs /ɾ/ vs /ɻ/. As Tables 2 and 3 show, however, there is a substantial overlap in their phonetic realization. There is, furthermore, a range of potentially lenited realizations associated with each contrastive phoneme. The trill has three realizations: /r/ → [ɹ], [ɾ], [r]. Two of these allophones, [ɾ] and [ɹ], also constitute the realization set for the tap /ɾ/.

		Allophonic Realizations			
Proposed Phoneme		alv trill [r]	alv tap [ɾ]	alv cont [ɹ]	rfx cont [ɻ]
alv trill	/r/	**112**	66	92	6
alv tap	/ɾ/	0	33	**100**	0
rfx cont	/ɻ/	0	1	1	**62**

Table 4: Frequency of realizations for proposed phonemes.

For the retroflex continuant /ɻ/ we expect only one realization and no interaction with the alveolar series; this is essentially the situation reported in Table 3. However, there are six tokens of [ɻ] which overlap with tokens that have been assigned the phoneme /r/, as well as two tokens assigned with the phoneme /ɻ/ that are realized as an alveolar tap or continuant.

4. DISCUSSION

Our results are largely consistent with Hercus' [6] description. Hercus reports that there is a three-way rhotic contrast (/r/ vs /ɾ/ vs /ɻ/) in Ons1 position. Our data shows this contrast: [k**ara**nda] 'to tie up' vs [**aɾa**ta] 'above' vs [k**aɻa**da] 'north wind'. Hercus reports that even in Ons1 position both /r/ and /ɾ/ can be realized as [ɾ] at faster speech rates. Our data supports this even at normal speed. However, our data shows that the overlap is not limited to [ɾ] realizations, but also includes [ɹ] realizations. Indeed [ɹ] realizations are the commonest realizations of /r/ and /ɾ/ across all positions (48% vs 28% for [r] and 25% for [ɾ]).

We suggest the three-way distinction presents perceptual difficulties because of the significant overlap in the realization sets of /r/ and /ɾ/. Tables 2 and 3 show that the realization set [ɾ, ɹ] of the tap /ɾ/ is a subset of the realization set [r, ɾ, ɹ] for the trill /r/. For both phonemes, the continuant [ɹ] is the most frequent realization. The distinction between /r/ and /ɾ/ is that /r/ permits [r] realizations, whereas /ɾ/ does not. Due to the large overlaps and the not immediately predictable nature of the allophony, a large number of tokens are needed for any individual word, before the assignment of [ɹ] and [ɾ] realizations to either of the alveolar rhotic phonemes, /r/ and /ɾ/, can be determined.

In Ons2/3 position, Hercus [6] reports that /ɻ/ is contrastive, but there is no /r/ vs /ɾ/ contrast. We also find a distinction between the retroflex and trill in this context. However, our data also shows evidence for a /r/ vs /ɾ/ distinction: [kal**ara**] ('cloud') vs [kung**ara**] ('kangaroo').

There was no evidence for rhotic contrasts in coda position in our study, nor did we find instances of a retroflex [ɻ] realization in this context. In coda position, Hercus [4] reports that the place of the following onset affects realizations, with laminal onsets favouring [r] realizations. We did not examine this factor. We found that vowel environments have a significant effect on realizations in all positions, including coda positions, with i_(C)i favouring continuant [ɹ] realizations (see Table 2). Hercus does not discuss vowel environments. As [r] realizations occur with significant frequency in coda position (see Table 2), and as other realizations can be explained on the basis of the lenition pathway shown in Table 3, we analyse the neutralized coda rhotic as the trill phoneme /r/.

5. CONCLUSION

Our study supports Hercus' [6] principal analysis: (1) that there is a three-way rhotic contrast in Arabana; (2) that this contrast presents significant perceptual difficulties; (3) that this contrast is subject to prosodically conditioned neutralization. We ground the perceptual difficulties in the high degree of overlap in realization sets between the alveolar rhotics. The relationship between overlap and perceptual difficulties, as well as Hercus' reports of prosodically conditioned neutralization, are topics for future research.

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